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EPA-BBW Correlation Program

Abstract

Exhaust emission and gas cylinder analysis data were gathered at the EPA laboratory and at the new BBW test facility in Farmington. The two laboratories agreed closely in the measurement of CO. Although there were significant differences in the measured levels of HC, NO and CO_2, it is believed that these discrepancies were caused by differences in dynamometer type and ambient conditions. Because of the limited amount of testing done, it was not possible to generate ambient correlation factors for the exhaust emissions.

EPA-BMW Correlation Program

1. Introduction

BMW has recently completed construction and instrumentation of a light-duty vehicle exhaust emission test cell in the Detroit area. The facility is located at Erhart Motors at 31715 Grand River in Farmington. The facility became operational on approximately May 1, 1975. BMW requested a correlation test program with the EPA automotive laboratory in order to assess the operation of their new test facility.

2. Technical Discussion

2.1 Program Objective

The purpose of this study is to determine any differences in exhaust emission tests, fuel economy tests and gas cylinder analysis tests at EPA facilities and the BMW laboratory. In addition to comparing these test results, this study also compares the test equipment used at each facility.

2.2 Facilities and Equipment

2.2.1 Test Sites

The BMW facility consists of one test cell which has temperature but not humidity control. EPA used their designated "master cell" which is cell number 5. This facility has both temperature and humidity control.

The equipment and instrumentation used within each test cell is listed in Table 1. Perhaps the most significant difference in test equipment is the dynamometers. The EPA used a direct-drive inertia wheel unit, while BMW has the belt-driven type.

2.2.2. Test Vehicles

One test vehicle was used in this program. This was a 1975 3.0 SI BMW equipped with a 4-speed manual transmission. The engine was an electronic fuel-injected 6-cylinder, equipped with a thermal reactor. The inertia and actual h.p. setting for this vehicle were 3500 lbs. and 11.2 h.p., respectively. The same fuel (commercial leaded) was used for all tests.

2.3 Program Design

The test was designed so that, after several vehicle tests had been done at BMW, three tests would be conducted at the EPA. The day prior to testing at the EPA, five tests were conducted at BMW. For purposes of the statistical analysis, the last three of these tests were used. In addition to vehicle tests, a set of gas cylinders was also analyzed at each lab.

Table 1 Test Site Equipment and Instrumentation

	EPA	B/W
Analyzers		
HC	Beckman 400, 0-30 ppmC, H_2/N_2 fuel	IIR Model 855, 0-100 ppmC, 100% N_2 fuel
CO	Bendix 8501, 0-500 ppm	B&R Type 2T, 0-500 ppm
NO_x	TECO 10A, 0-100 ppm, O_2 Ozone Source	TECO 10, 0-100 ppm, Air Ozone Source
CO_2	Beckman 315A, 0-3, 3%	B&R Type 2T, 0-2%
Analyzer Bench	Homebuilt according to Federal Register	Homebuilt according to Federal Register
CO Conditioning Agents	Ascarite, Silica Gel in Common Tube	Ascarite, Silica Gel in Separate Tubes
CVS	Ford Philco, CFV	Bonte 302, 0-Bag, ΔP = 22" H_2O
Dynamometer	Clayton CT-50, Direct-Drive Inertia, Auto Loading not used	Clayton C150, Belt-Drive Inertia, Manual Loading
Driver's Aid	Varian, 5" = 60 mph, 6"/min. Preprinted Trace	Servogor, 7.6" = 60 mph 12 cm/min, Hand-made trace
Computer	IBM 370, Off-line	Hand-calculated

2.4 Test Procedure

2.4.1 Vehicle Preparation

All vehicle tests were "hot-start" as vehicle preconditioning consisted of stabilizing the vehicle at some constant condition prior to the start of each test. Oil temperature was used as the control condition. Prior to testing, the vehicle was operated at a steady speed of 25 mph until the oil temperature rose to 72°C. Then the vehicle was brought to an idle. When the oil temperature reached 75°C (167°F) the test was begun.

2.4.2 Emission Tests

The driving cycle used was the urban dynamometer driving schedule (LA-4). The vehicle began the cycle at idle with an oil temperature of 75°C. Emissions were measured according to the 1974 FTP. Between each test the vehicle was shut-off and allowed to cool for approximately 15 minutes so that the following test could be started at an oil temperature of 75°C.

2.4.3 Fuel Consumption Tests

Fuel Economy was calculated for each LA-4 cycle based on the carbon balance technique as described in the Federal Register.

2.4.4 Cylinder Gas Check

Five gas cylinders were analyzed at both test sites. These cylinders were analyzed on the same analyzer trains that were used for the vehicle emission tests. Three concentrations of CO_2 (nominally 0.0%, 1.7%, and 3.7%) and two concentrations of CO (nominally 170 ppm and 1300 ppm) were used.

3. Data Analysis

In addition to the calculation of means and standard deviations for HC, CO, CO_2, NO_x and fuel economy at each test site, a Student's "t" test was used to detect any significant differences between the test sites.

4. Test Results

4.1 Emission and Fuel Economy Data

Data and statistical analysis results from the emission and fuel economy tests are contained in Table II. As shown, the two labs agreed in CO measurements however, the 10.1% difference in CO_2 showed high statistical significance. The MVMA lab measured 20.4% lower HC and 13.3% higher NO_x and these differences were at the 97% and 96% confidence level, respectively. Repeatability of the HC measurement was much poorer than repeatability of the other emissions.

Table II Vehicle Emission and Fuel Economy Data and Statistical Analysis Results (Data uncorrected for any ambient or instrumentation difference)

Test	HC_2, $\frac{gm}{mi}$	CO, $\frac{gm}{mi}$	CO_2, $\frac{gm}{mi}$	NO_x, $\frac{gm}{mi}$	Fuel Economy, $\frac{mi}{gal}$
BMW					
1	0,54	7,60	656	2,26	13,3
2	0,66	7,49	647	2,06	13,4
3	0,51	7,58	654	2,09	13,3
$\bar{X}$	0,563	7,42	653	2,14	13,35
σ	,068	0,20	4,7	0,11	,06
$\sigma,\%$	12,1 %	2,7 %	0,7 %	5,0 %	0,4 %
EPA					
4	0,71	7,58	595	1,91	14,6
5	0,90	7,37	585	1,89	14,8
6	0,78	7,62	585	1,87	14,8
$\bar{X}$	0,796	7,52	588	1,890	14,73
σ	0,096	0,13	5,77	,020	0,12
$\sigma,\%$	12,0 %	1,7 %	0,9 %	1,0 %	0,8 %
$\bar{X}_{BMW}-\bar{X}_{EPA}$	-0,233	-0,10	64	,25	-1,40
$\frac{\bar{X}_{BMW}-\bar{X}_{EPA}}{\bar{X}_{EPA}}$ x100%	-29,3 %	-1,3%	10,9%	13,2 %	-9,5 %
t-value	3,43	,72	-14,06	-3,89	-18,78
Confidence Level	97 %	<60 %	>99,9 %	98 %	>99,9 %

Due to the fact that each facility tested on only one day, the ambient conditions changed very little within each test site. Therefore, it is not reasonable to attempt to obtain ambient correction factors for this vehicle. Also, there were only very small differences in temperature and humidity conditions between the test sites. However, the barometric pressure at EPA was about 0.6 in.Hg lower than at BMW. In an attempt to adjust the data for this difference in barometric pressure, the correction factor obtained from the 1975 HVIIA correlation study[1] was applied to the data. In doing this, it was assumed that barometric pressure had the same percentage effect on the emissions from vehicles used in both studies. But, obviously, correctness of the result depends on validity of this assumption. In the HVIIA study, a 0.6 in.Hg difference in barometric pressure would have accounted for nearly 30% of the observed difference in NO_x and about 20% of the observed difference in HC in the BMW-EPA data. And these adjusted differences are at the 96% confidence level, which is a significant reduction of the 97% and 95% confidence level of the uncorrected data.

Also in the 1975 HVIIA study, a difference in dynamometer load was observed between direct-drive and belt-driven inertia wheels; and this resulted in a significant effect on NO_x. The HVIIA program yielded a dynamometer type vs NO_x relationship which could account for about 35% of the observed NO_x difference in the BMW-EPA data.

The statistically significant difference of 10.9% in CO_2 values cannot be explained by dynamometer and/or ambient effects. Results of the 1975 EPA-HVIIA correlation study indicate that about a 4% difference could be a dynamometer difference and about 1% could be attributed to the difference in barometric pressure. But the remaining 6% difference would still be significant at greater than a 99% confidence level.

4.2 Gas Cross-check Tests

Results of the five gas cylinder analyses are shown in Table III. As listed, the only analysis that was not in good agreement was the nominal 1.7% CO_2. BMW measured this concentration as being 4.2% higher than did the EPA. Since this analysis was conducted on the same analyzers that were used for the vehicle test, this discrepancy accounts for part of the 10.9% observed difference in CO_2 emissions. Taking into account the 4.2% analyzer difference, a 4% dynamometer effect and a 1% barometric pressure effect, the 10.9% observed difference in CO_2 is reduced to only about a 2% difference.

5. Conclusions

1. CO data showed good agreement between the two laboratories.

2. Differences in dynamometers (direct-drive vs belt-driven inertia) and barometric pressure are believed to be responsible for the observed differences in NO_x values.

Table III

Results of Gas Cylinder Cross-Checks

Gas	NBW	EPA	Δ(NBW-EPA)	Δ,%
CO	169 ppm	167,5 ppm	1,5 ppm	0,9
CO	1321 ppm	1323,9 ppm	-2,8 ppm	-0,2
CO_2	0,60 %	0,60 %	0,00	0,00
CO_2	1,74 %	1,67 %	0,07 %	4,3
CO_2	3,24 %	3,21 %	0,03 %	0,9

3. The only difference in gas cylinder analysis greater than 1% was a 4.2% difference (EPA higher than BMW) on a CO_2 concentration of about 1.7%.

4. The above mentioned 4.2% differences in CO_2 analysis is responsible for part of the observed CO_2 emission difference of 10.9%. The remaining difference is believed to be caused mostly by differences in dynamometer type and barometric pressure.

6. Recommendations

1. In future correlation work, it would be desirable to have testing performed at one location on more than one day. This would most likely result in greater ambient condition variations within each laboratory and would make possible the calculation of ambient correction factors.

2. During vehicle tests at BMW the test cell temperature rose from about 71°F at the beginning of a test to approximately 83°F at the end of the test. Decreasing this temperature rise would most likely improve testing repeatability. (The temperature range encountered during the EPA tests was from 72°F to 78°F.)

3. Dynamometer type should be standardized or quantitatively characterized in order to improve laboratory correlation.

References

1. Lutfovan, H. and Wilson, G., "1975 EPA-U.S. HVMA Emission Laboratory Correlation Study", Environmental Protection Agency, Office of Air and Waste Management, Office of Mobile Source Air Pollution Control, Emission Control Technology Division.